PRIMARY INOCULUM OF *Pyrenophora tritici-repentis* ON WHEAT AS AFFECTED BY CULTURAL CONTROLS IN REDUCED TILLAGE, AND ITS EFFECT ON EPIDEMIC DEVELOPMENT

by

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INTRODUCTION

Pyrenophora tritici-repentis (Died.) Drechs. [anamorph: Drechslera tritici-repentis [Died.) Shoem.], is an ascomycete which causes tan spot, a foliar leaf disease of wheat and other grasses (9). The fungus survives between crops of wheat on infested wheat residue, saprophytically colonizing the tissue. Ascocarps are initiated in the summer or fall and mature, following a cold period, early the following spring. The ascospores are then ejected up to 5 cm in still air (B. Norman, personal communication) and function as primary inoculum on young wheat plants (7). If the surface of the leaf is wet for a sufficient time period the ascospore germinates, infects the host and the hyphae grow through the leaf tissue, resulting in a characteristic necrotic spot surrounded by a yellow halo.

Secondary cycles of tan spot are initiated by conidia formed on older lesions and blown to new infection sites on healthy leaf tissue (16). The conidia can be dispersed up to 50 miles by winds (7).

The severity of the tan spot epidemic depends on the amount of inoculum (5,21), the growth stage of the wheat plant at infection (19,24), the resistance of cultivars (19), length of wet period and temperature (10). In comparison with conventional tillage methods,the increased residue left on the soil surface for erosion control in reduced tillage practices (3) has increased the prevalence of tan spot. Though

all elements of the epidemic (host, environment, and inoculum), along with agricultural chemicals, are areas relevant to control, the primary emphasis of this research was to evaluate methods of control through reduction of primary inoculum.

The first chapter of the thesis describes experiments conducted to determine if different levels of primary inoculum are related to the amount of disease during the growing season and subsequent yield loss.

The second chapter describes an experiment to test different herbicides commonly used in reduced-tillage wheat farming for their effect on ascocarp formation by P. tritici-repentis on naturally infested wheat straw. The use of herbicides for such a dual purpose could be an effective way of reducing primary inoculum, which is shown in chapter 1 to be important in reducing the amount of disease.

The third chapter is also based on the results of chapters 1 and 2 and looks at the effects of different tillage practices in combination with an herbicide on ascocarp production. If certain tillage practices reduce primary inoculum by favoring a competitor or antagonist of P. tritici-repentis or making the microclimate unfavorable for the fungus, it would be very useful information to the farmer.

CHAPTER 1: THE EFFECT OF PRIMARY INOCULUM OF *P. tritici-repentis* ON EPIDEMIC DEVELOPMENT

INTRODUCTION

Pyrenophora tritici-repentis is the causal organism of tan spot disease on wheat (*Triticum aestivum*) (7), epidemics of which can cause up to 49% yield loss (22). The importance of tan spot is increasing with the increased emphasis on conservation tillage practices for erosion control (3,26). This is due to the ability of *P. tritici-repentis* to survive saprophytically between cropping seasons in infested stubble on or above the soil surface (9,15).

It has been shown that increased amounts of residue infested with *P. tritici-repentis* can produce increased amounts of disease (5,22) and increased yield loss (22). However, the quantity of the inoculum (number of ascocarps/g of infested straw) was not measured in these studies. Preventing the number of ascocarps/m^2 necessary to cause significant yield loss is important in determining methods to control the number of ascocarps produced on residue. In using wheat residue for erosion control in a monoculture it would be desirable to lower the inoculum quantity to a level where there would be no significant losses due to tan spot, but still have sufficient residue for erosion control.

The purpose of this field experiment was to determine what number of ascocarps/m^2 is necessary to significantly increase the Area Under the Disease Progress Curve (AUDPC) and

reduce yield compared to plots with no primary inoculum.

METHODS AND MATERIALS

To simulate field conditions, naturally infected straw was used. Straw was collected from research plots infested with P. tritici-repentis, and stored indoors in burlap bags over the summer. From September 8 to November 14, the straw was placed outdoors on a frame of wire net 5 cm above the ground where it would be exposed to light and moisture early in the fall to initiate ascocarp development.

In November the amount of inoculum on the straw was measured by counting the number of mature ascocarps (>300um in length) on the culm tissue (16). The heads, sheaths and leaves were removed and discarded before counting. Ascocarps/g were calculated after counting two samples of two grams each for each of the medium and high level plots. The entire number of ascocarps were counted for the low levels.

Field plot were infested with four levels of inoculum based on residue and inoculum levels reported by other investigators (5,22). In the first experiment (1986-87 cropping year), the amounts of infested residue used were 97, 9.7, 0.97, and 0 g/m^2. Since culms averaged 260 ascocarps/g , this equalled 25,000, 2,500, 250, and 0 ascocarps per m^2, respectively.

For the second field experiment (1987-88 cropping year), the levels of infested residue used were 95.2, 5.5, 0.5, and 0 g/m^2. The straw supported 1050 ascocarps/g of

culm, so the ascocarp levels per m^2 were 100,000, 5,000, 500, and 0 respectively. There were also controls with no infested residue applied.

The total amount of residue in each plot (including checks) was brought to 100 grams per m^2 using oat straw not infested with the pathogen. The infested oat and wheat straw was spread on the plots in the first half of December both years. Straws were sampled, in March, from the high-inoculum plots to determine the percent of ascocarps that had developed ascospores.

The plots were arranged in a randomized complete block design with three replications. There was one block without a control treatment the first year due to a lack of space.

The plots were 1.5 x 1.5 m (6 rows of wheat) the first year and 1.2 x 1.8 m (5 rows of wheat) the second. There was a 3 meter border of wheat around each plot. There were $\geq$ 13 meters of fallow ground between plots.

Arkan was the winter wheat variety planted the first year, and Rohm and Haas 7837 (Rohm and Haas Seed, Inc. Rt. 1 Box 45B, Mt. Hope, KS 67108) was the winter wheat planted the second year for improved leaf rust (Puccinia recondita) resistance. The plots were planted with a 5-row hoe drill at 23-cm row spacing. They were planted September 25 the first year and October 6 the second year.

Disease ratings were determined every 5-8 days following appearance of the initial tan spot infections in the spring.

The rating included a severity measurement that included the quality of the lesion and the area of infected tissue per leaf (19). The severity scale (0 - 5) was: 0 = no disease; 1 = very small lesions or flecks, <10% leaf area infected; 2 = necrosis with yellow halo, <10% leaf area infected; 3 = lesions coalesced, 10-50% leaf area infected; 4 = 50-100% leaf area infected with some green tissue left; 5 = total leaf senescence.

For sampling, each row was divided into approximately 22 sections 7 cm in length, and two sections were randomly selected from each of 5 rows in a plot. Two plants from each section were randomly selected to be rated, providing a total of 20 plants per plot. The top two leaves were rated in both years. The first rating was March 19 the first year and April 5 the second. The last rating was taken May 12 the first year and May 26 the second year. In the first year, an epidemic of leaf rust (P. recondita) caused early senescence of the leaves; after May 12 it was impossible to distinguish tan spot infections from other chlorotic symptoms.

On June 6 (the wheat at mid-dough stage) the second year, 10 penultimate leaves were randomly sampled from each plot. On June 7, 10 flag leaves were randomly sampled from each plot. Five leaves were randomly selected from each sample, surface sterilized, cut into 1-cm lengths, and 10 sections alternately selected to be plated on Septoria Selective Agar (SSA)(10 g agar, 200 mg chloramphenicol, 0.42 mg triphenyl tin

hydroxide, 1000 ml H_2O). After 1 week of incubation at 23°C with a photoperiod of 12 hours light 12 hours dark, the leaf sections were scored under a disecting scope at 500x for the presence of P. tritici-repentis, as indicated by conidia and/or ascocarps.

The individual plots were harvested by hand June 15 the first year and June 13 the second year. Total grain weight, test weight, and 1000 kernel weight were recorded for each plot.

The ratings for disease severity on the top two leaves were plotted versus time for the duration of the rating period, and the areas under the disease progress curves (AUDPC) for leaves 1 and 2 were calculated and averaged together. Leaf 3 was not included in the analysis because it senesced earlier from undistinguishable causes. The AUDPC values were analyzed using Analysis of Variance (ANOVA) on SAS (23). The relationships of inoculum levels to AUDPC, yield and 1000 kernel weight were also analyzed using linear regression (23) for both years individually.

RESULTS

Progression, for both years, of the average leaf ratings for the top two leaves, at each rating period, for each inoculum level are shown in Figures 1-1 and 1-2.

The average AUDPC for both years are shown in Table 1-1. In 1987 the AUDPC for the high-inoculum treatment was significantly (unless otherwise noted P = 0.05) greater than

that for the medium-inoculum treatment and both were significantly higher than the AUDPC's for the low and control-inoculum treatments. The low and control AUDPC's were not significantly different from each other. In 1988 the AUDPC for the high-inoculum treatment was again significantly greater than all the other levels of inoculum. The AUDPC for the medium, low and control levels were not significantly different.

The average yields (bushels per acre) for each inoculum level for both years are shown in Table 1-2. The yields for the medium, low and control-inoculum levels in 1987 were not significantly different from each other but were significantly higher than the yields from the high-inoculum treatments. In 1988, the control treatment yields were significantly greater than the high-inoculum treatment yields, but were not significantly greater than the low-inoculum plots. The high-inoculum yields were not significantly lower than the medium and low-inoculum yields.

The average 1000 kernel weights for each inoculum level are shown in Table 1-3. In both years there was no significant difference in 1000 kernel weights among the different inoculum levels.

The linear regression between the logarithm of AUDPC (LAUDPC) and the logarithm of inoculum (LINOC) for both years was significant. In 1987,the model describing the regression was LAUDPC = 0.48(LINOC) + 1.09; R^2 = 0.90, 11 df. In 1988,

the model was LAUDPC = 0.15(LINOC) + 2.09; R^2 = 0.65, 11 df. These regressions are shown in Figure 1-3.

The linear relationship between yield (bushels/acre) and LAUDPC was not significant in 1987 but was (P = 0.08) in 1988. A plot of the data is shown in Figure 1-4.

The linear regression between yield and LINOC was not significant for either year. A plot of the data is shown in Figure 1-5.

There was no significant relationship between 1000 kernel weight and LINOC for either year.

Combining the data from both years for analysis did not improve any of the relationships significantly.

The percent of P. tritici-repentis-infected wheat leaf tissue collected after senescence of the leaves is shown in Table 1-4. The percent infected area is higher on leaf 1 (flag leaf) than on leaf 2 in every treatment except the high-inoculum treatment, however the statistical analysis was not run. On leaf 1 the high-level treatment was not statistically different from the medium- and low-inoculum levels, but was different from the control. The medium, low and control levels were not statistically different from each other. For leaf 2 the high-level was statistically different from the other levels and the medium, low, and control levels were not significantly different form each other.

The regression analyses of the final infection percent are shown in Table 1-5. Infection levels on both leaves were

significantly related to LINOC and LAUDPC, but the higher R^2 and lower P-value for leaf 2 than leaf 1 in the regressions against the LAUDPC show that the AUDPC's were more closely related to the percent of infected tissue on leaf 2 than leaf 1. The regression analysis of leaf 1 and leaf 2 against LBU was not statistically significant.

DISCUSSION

The amount of primary inoculum of P. tritici-repentis was shown to have a significant effect on tan spot epidemic development (AUDPC) for both years (Figure 1-3). The two years had very different weather conditions, with the rainy weather in 1987 being very favorable for a tan spot epidemic, and 1988 a poor epidemic year with very hot and dry conditions. The ANOVA and the regression analysis both confirmed the positive relationship between AUDPC and the amount of primary inoculum. The lack of significant differences between the low and control-inoculum levels in 1987, and the medium, low and control-inoculum levels in 1988 suggest that adequate control of tan spot could be achieved if these levels of ascocarps/m^2 were present in a field, under the same conditions as in their respective years. The 1988 AUDPC figures probably would have been higher and shown more differences among the inoculum levels had the weather been more conducive for a tan spot epidemic, as in 1987.

The relatively low influence of primary inoculum on yield could be because there were many factors affecting the yield

other than tan spot epidemic severity. In 1987, a severe epidemic of leaf rust (Puccinia recondita) at the dough stage of grainfill greatly reduced the yields in all plots. The control and low-inoculum plots appeared to have more rust pustules per leaf than the medium- and high-inoculum plots. Therefore, the yields of the control and low-inoculum plots were affected proportionally more by the rust epidemic than yields of the medium- and high-inoculum plots. In 1988, the increased high-inoculum level (from 25,000 in 1987 to 100,000 ascocarps/g in 1988) did significantly lower the yields from the other inoculum levels as the high-inoculum level had in 1987, but the yield loss could have been greater had the conditions been more favorable for a tan spot epidemic.

The 1000 kernel weight was not significantly related to primary inoculum or AUDPC in either year because of the conditions mentioned previously. The rust epidemic and drought were present at the wheat growth stage when the kernel weights are determined, and masked the effect of the tan spot epidemic.

The results of plating the leaf tissue may reflect the occurrence of an infection period after the second leaf had senesced, resulting in a higher percent of infected leaf area on the first leaves than on the second leaves in the medium, low and control level plots. The high-level plots may have had a large percent of leaf 1 tissue already infected before this later infection period. The higher percent of infection

in leaf 1 than in leaf 2 in the lower-level plots and the lower percent of infection in leaf 1 than in leaf 2 in the high-level plot could mean that the secondary inoculum from other fields could have an effect on the amount of disease and yield loss when the amount of disease is relatively low. However, the statistical differences in percent infection between the high and control inoculum plots show that the primary inoculum was influential in the amount of disease throughout the season and yield loss. The importance of primary and secondary inoculum sources could vary between years with the primary inoculum more important in the years less favorable for tan spot epidemic conditions. Also, the importance of either inoculum source could vary depending on the proximity of another inoculum source. The closer another source of inoculum the more important the secondary inoculum to the final amount of disease. Proximity of external inoculum could have been influential in these experiments, due to the relative closeness of the plots to each other and other inoculum sources (1).

In conclusion, this experiment has shown that the amount of disease is directly related to the amount of primary inoculum in two very different years of field research. However, since there are many other factors that determine the yield of a crop, the relationships of yield to AUDPC and primary inoculum are harder to demonstrate. More replications would have reduced the variability and shown more differences.

There also appeared to be a 'threshold' level of ascocarps/m^2 to cause significant disease increases and yield losses in both years.

FIGURE 1-1

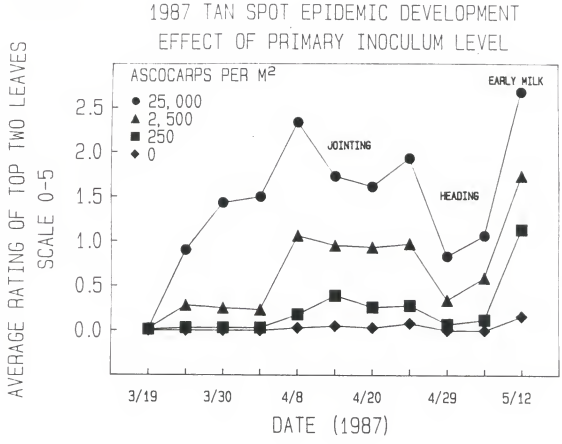
1987 TAN SPOT EPIDEMIC DEVELOPMENT
EFFECT OF PRIMARY INOCULUM LEVEL
ASCOCARPS PER M2
25,000
2,500
250
0
EARLY MILK
JOINTING
HEADING
AVERAGE RATING OF TOP TWO LEAVES
SCALE 0-5
2.5
2.0
1.5
1.0
0.5
0.0
3/19
3/30
4/8
4/20
4/29
5/12
DATE (1987)

FIGURE 1-2

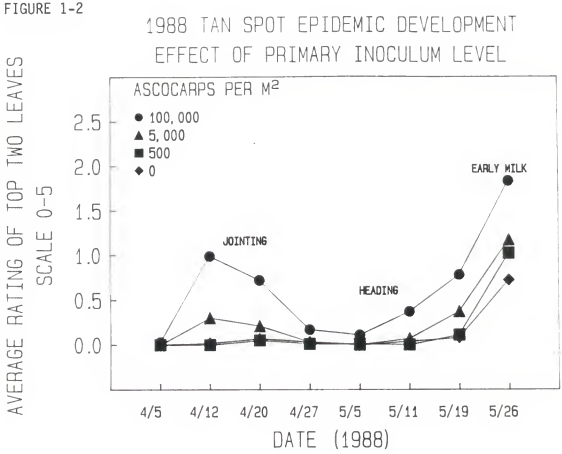
1988 TAN SPOT EPIDEMIC DEVELOPMENT
EFFECT OF PRIMARY INOCULUM LEVEL
ASCOCARPS PER M2
● 100,000
▲ 5,000
■ 500
◆ 0
EARLY MILK
JOINTING
HEADING
AVERAGE RATING OF TOP TWO LEAVES
SCALE 0-5
2.5
2.0
1.5
1.0
0.5
0.0
4/5
4/12
4/20
4/27
5/5
5/11
5/19
5/26
DATE (1988)

TABLE 1-1

THE EFFECT OF PRIMARY INOCULUM OF P. tritici-repentis ON THE AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC)

1987		1988	
INOCULUM LEVEL[y]	AUDPC[z]	INOCULUM LEVEL[y]	AUDPC[z]
25,000	76.5 A	100,000	24.0 A
2,500	34.6 B	5,000	11.0 B
250	10.8 C	500	5.2 B
0	1.3 C	0	4.9 B

y. Ascocarps per m^2
z. Numbers followed by different letters are significant (P= 0.05) differences computed from SAS Least Squares Means.

TABLE 1-2

THE EFFECT OF PRIMARY INOCULUM OF P. tritici-repentis ON YIELD

1987		1988	
INOCULUM LEVEL[y]	YIELD (bu/A)[b]	INOCULUM LEVEL	YIELD[b]
25,000	12.8 A	100,000	58.6 A
2,500	18.8 B	5,000	59.5 A
250	18.3 B	500	64.0 AB
0	17.5 B	0	65.2 B

y. Ascocarps per m^2
z. Numbers followed by different letters are significant (P= 0.05) differences computed from SAS Least Squares Means.

TABLE 1-3

THE EFFECT OF PRIMARY INOCULUM OF P. tritici-repentis ON 1000 KERNEL WEIGHT

1987		1988	
INOCULUM LEVEL[y]	WEIGHT(g)[z]	INOCULUM LEVEL[y]	WEIGHT[z]
25,000	20.5 A	100,000	21.8 A
2,500	20.3 A	5,000	23.7 A
250	20.4 A	500	24.3 A
0	21.3 A	0	22.8 A

y. Ascocarps per m^2

z. Numbers followed by different letters are significant (P= 0.05) differences computed from SAS Least Squares Means.

FIGURE 1-3

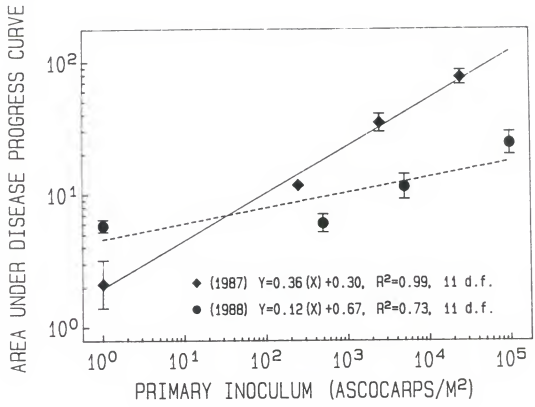
AREA UNDER DISEASE PROGRESS CURVE
10^2
10^1
10^0
◆ (1987) Y=0.36 (X) +0.30, R^2=0.99, 11 d.f.
● (1988) Y=0.12 (X) +0.67, R^2=0.73, 11 d.f.
10^0 10^1 10^2 10^3 10^4 10^5
PRIMARY INOCULUM (ASCOCARPS/M2)

FIGURE 1-4

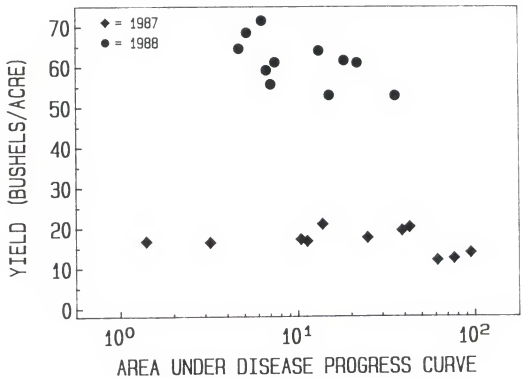
◆ = 1987
● = 1988
YIELD (BUSHELS/ACRE)
70
60
50
40
30
20
10
0
10^0
10^1
10^2
AREA UNDER DISEASE PROGRESS CURVE

FIGURE 1-5

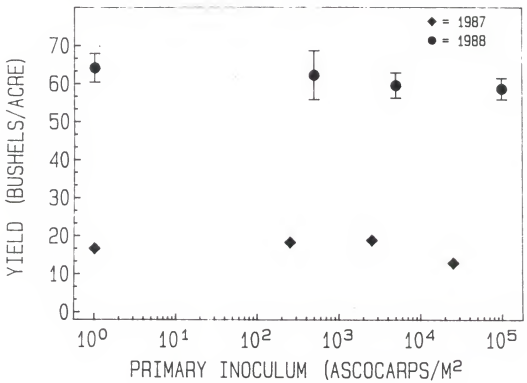
◆ = 1987
● = 1988
YIELD (BUSHELS/ACRE)
70
60
50
40
30
20
10
0
10^0
10^1
10^2
10^3
10^4
10^5
PRIMARY INOCULUM (ASCOCARPS/M²)

TABLE 1-4

PERCENT WHEAT LEAF TISSUE INFECTED WITH *P. tritici-repentis* AT SENESENCE OF LEAVES IN 1988

INOCULUM LEVEL[x]	LEAF 1 PERCENT[yz]	LEAF 2 PERCENT[y]
100,000	70 A	87 A
5,000	68 AB	48 B
500	66 AB	44 B
0	39 B	25 B

x. Ascocarps per m^2
y. Numbers followed by different letters are significant (P= 0.05) differences computed by SAS Least Squares Means.
z. Unprotected Least Significant Differences, ANOVA not significant.

TABLE 1-5

REGRESSION ANALYSIS OF PERCENT OF WHEAT LEAF TISSUE INFECTED WITH *P. tritici-repentis* AT SENESENCE OF LEAVES IN 1988

DEPENDENT VARIABLE	INDEPENDENT VARIABLE[z]	R^2	PROB. > 'T'
LEAF 1	LINOC	.57	0.007
LEAF 2	LINOC	.64	0.003
LEAF 1	LAUDPC	.38	0.04
LEAF 2	LAUDPC	.65	0.003
LEAF 1	LBU	.33	0.06
LEAF 2	LBU	.11	0.31

z. LINOC = LOG_{10} (INOCULUM + 1)
LAUDPC = LOG_{10} (AREA UNDER THE DISEASE PROGRESS CURVE)
LBU = LOG_{10} (BUSHELS PER ACRE)

CHAPTER 2: EFFECTS OF HERBICIDES ON ASCOCARP PRODUCTION OF *P. tritici-repentis*

INTRODUCTION

The importance of tan spot, a foliar wheat (*Triticum avestivum*) disease caused by *Pyrenophora tritici-repentis* (Died.) Drechs., has increased with the use of conservation tillage. Compared with conventional tillage, conservation tillage increases the amount of surface residue to control wind and water erosion (3,26). If this residue is infested with *P. tritici-repentis* it results in a higher amount of primary inoculum compared with conventional tillage practices, where little residue is left on the soil surface (5).

Pyrenophora tritici-repentis is an ascomycete fungus which produces ascocarps saprophytically on infested plant tissue. In the spring, ascospores mature and are released as primary inoculum for a tan spot epidemic on wheat. It has been shown that the amount of disease and yield loss is directly related to the amount of residue infested with *P. tritici-repentis* (5,22). Further, it has been shown, in experiments where the amount of residue was kept constant, that the number of ascocarps/m^2 is directly related to the amount of disease and yield loss (Chapter 1, this thesis). Since previous studies have shown that different herbicides have activity on fungi (4,6,11), the use of herbicides for the dual purpose of controlling weeds and also reducing primary inoculum of *P. tritici-repentis* could be economically

beneficial for the farmer.

The objective of this experiment was to test herbicides commonly used in wheat farming for their effect on ascocarp production in naturally infected wheat straw.

METHODS AND MATERIALS

The straw, from research plots infested with P. tritici-repentis, was collected after the wheat was harvested in 1986. The straw was stored in burlap bags indoors. There were no ascocarps or ascocarp initials on the straw at the time it was used for experiments.

Two 5-cm pieces of straw were taken from above each of the top two nodes. In the first experiment, a comparison was made between the number of ascocarps produced on the peduncle and top internode. A statistical analysis showed no difference between the two sections, so the data were analyzed together and no distinction was made between the sections in the second experiment. Half of the straw pieces had the sheath tissue intact and the sheath was removed from the other pieces. A statistical analysis was also made between the number of ascocarps produced on culms with and without sheath. An equal number of each was used in both experiments (10-16 straws).

The chemicals screened were selected from those listed for wheat application in Kansas (13) including two miticides commonly used in the greenhouse (Mavrik and Pentac), and three experimental foliar fungicides (Spotless, HWG 1608, and Tilt). No mixtures or combinations of chemicals were used. The

maximum rates listed for each chemical were used, along with the minimum amount of carrier recommended, resulting in the highest concentration labeled for use in the field (Table 2-1). If the amount of carrier was not mentioned, the rate used was that recommended by weed-control researchers (L. Moshier, personal communication).

In the second experiment, the chemicals that performed the best in the first experiment were used again. Those were 2,4-D, Banvel, Buctril, Paraquat, and Roundup.

Two types of control treatments were used, water and water plus surfactant. The surfactant used was an experimental product from Cargill (Minneapolis, Mn), 497-30-B. One 0.1 ml was added to 80 ml of distilled water (1 pt/100 gal.) This surfactant solution was used as the carrier for the chemicals that were recommended to be used with a surfactant (13).

The application method used in the first experiment was dipping the straws into the solutions in 16 x 100 mm test tubes. The dipping was chosen after comparing it with spraying 5 seconds at 10 psi with a Devilbiss Atomizer no. 152 because of the more thorough coverage of the straw. The spraying covered the straw with small beads of solution and the dipping covered the straw with a thin film of solution. In the second experiment, both methods of application were used.

After the chemicals were applied, the straws were

incubated in glass canning jars (946 ml) laid on their sides. A layer (250 cc) of vermiculite was spread on the bottom of each jar and moistened with 135 ml water. The straws were spaced evenly on the vermiculite. The lid of each jar had a hole (10 mm diam.) in the center to allow ventilation and heat exchange. In the first experiment, 16 straws were used per jar; 4 straws with sheaths from the first and second 5-cm section above the node, and 4 without sheaths. The second experiment had 10 straws per jar; 5 straws with and 5 without the sheath, with no distinction between first and second section.

The jars were placed on a greenhouse bench, where the air temperature was kept at 25 $\pm$ 5°C. After one month, ascocarp production waas assessed. Only the ascocarps larger than 300 um were counted because previous work (16) had shown that smaller ascocarps rarely produced ascospores.

The experiments were set up in a randomized complete block design. There were two replications (jars) for each herbicide in both experiments and for each application method in the second experiment.

The statistical analysis was the Kruskal-Wallis test for comparing non-parametric data, because of the non-normal distribution of the data (23). An analysis was performed on combined data of the dip application from both experiments.

RESULTS

In the first experiment, the numbers of large ascocarps (>300 um) per straw were counted (Table 2-2) (16). The five herbicides that resulted in the lowest number of ascocarps per straw were tested again in experiment two, as described previously, and the results tabulated (Table 2-2).

The statistical analysis of data from experiment two on culm vs. culm + sheath pieces in the number of ascocarps produced showed no significant (unless otherwise noted P= 0.05) difference in the number of ascocarps produced (Table 2-3).

There was a significant difference between the number of ascocarps produced with the dip vs. spray applications (Table 2-4), in the second experiment. The dip application inhibited ascocarp development of P. tritici-repentis more than the spray application.

The herbicides Banvel, Buctril, Paraquat, Roundup, and 2,4-D significantly reduced the number of ascocarps produced per straw when compared with the control and control + surfactant (Table 2-5) in the analysis using the combined data from the dip application in both experiments. Roundup-treated straw produced no ascocarps in either experiment, with either type of application, and number of ascocarps produced per straw was significantly lower than for the other herbicides.

The miticides Mavrik and Pentac, used in the first experiment, did not inhibit ascocarp production. The foliar

experimental fungicides Spotless and Tilt did not inhibit ascocarp production; HWG 1608 reduced ascocarp production only in the dip application. The data of the miticides and foliar fungicides were not included in any of the statistical analyses presented.

DISCUSSION

The effectiveness of Roundup in limiting development of P. tritici-repentis on naturally-infected straw in the greenhouse could be very beneficial to farmers, if field tests show similar results. If the farmer uses Roundup to control weeds in a stubble-mulch field prior to planting, the added benefit of reducing the primary inoculum of tan spot without additional cost would encourage the use of stubble-mulching to reduce erosion on more acres. More field research needs to be done with Roundup and other herbicides on their effectiveness for reducing the primary inoculum of P. tritici-repentis. Any one herbicide application will probably not result in total control for tan spot, so research needs to include different control measures in combination with herbicides.

The 10 weeks between the two experiments (January-March) may have lowered the overall number of ascocarps produced per straw in experiment two compared with experiment one. This may be due, in part, to reduced vigor of the fungus to produce ascocarps.

The higher effectiveness of the dip application over the

spray application in inhibiting ascocarp development could be due to the more thorough coverage of the straw by the herbicides. The dip application allowed the chemicals to come in contact with all exposed surfaces of the straw, possibly including the inside of the culm. These results point towards the importance of thorough coverage of the straw with the chemical in field applications for this purpose. Since it is not possible or practical to use dip application in the field, the use of chemicals for control of P. tritici-repentis should not be considered as complete, but instead as a way to reduce the primary inoculum level. Experiments in the future could investigate application rates and methods to increase the coverage and/or the absorption of the chemical into the straw.

The very high levels of ascocarps produced on straw treated with Atrazine, Bladex, Glean, and Lexone, which were similar to the controls, indicate these herbicides are not effective in limiting ascocarp production by P. tritici-repentis in wheat straw, even under optimum bioassay conditions.

The surfactant did not inhibit ascocarp production of the fungus, but instead slightly increased the ascocarps produced. One possible explanation is that the surfactant is limiting straw-borne bacteria which inhibit growth of P. tritici-repentis.

TABLE 2-1

HERBICIDES TESTED FOR EFFECTS ON ASCOCARP DEVELOPMENT OF *Pyrenophora tritici-repentis*

CHEMICAL	A.I./ACRE	PRODUCT/ACRE	CARRIER(H20)	PRODUCT/10ml
2,4-D (4 lb.)	1.5 lbs	3 pt.	3 gal.	1.25 ml
dicamba (Banvel)	2.0 lbs	4 pt.	5 gal.	1.0 ml
glyphosate (Roundup)	0.5 lbs	1 pt.	3 gal.*	0.417 ml
paraquat	0.93 lbs	2 pt.	20 gal.*	0.125 ml
atrazine (90%)	1.0 lbs	1.1 lbs	10 gal.	0.133 g
chlorsulfuron (Glean)	0.33 oz	0.5 oz	10 gal.*	0.004 g
cyanazine (Bladex 90%)	3.2 lbs	3.5 lbs	15 gal.	0.284 g
metribuzin (Lexone 75%)	0.75 lbs	1 lbs	10 gal.	0.120 g
bromoxynil (Buctril)	0.5 lbs	2 pt.	10 gal.	0.25 ml

* Surfactant added

TABLE 2-2

NUMBER OF *P. tritici-repentis* ASCOCARPS ON STRAW TREATED WITH HERBICIDES

PESTICIDE	ASCOCARPS PER STRAW[w]		
	EXP. 1(DIP)[x]	EXP. 2(DIP)	EXP. 2(SPRAY)
CONTROL	5.38	4.95	4.95
CONTROL + SURF.	6.47	8.80	5.85
dicamba (BANVEL)	1.59	0.00	2.30
bromoxynil (BUCTRIL)	1.63	0.25	2.60
paraquat	2.75	0.10	1.35
glyphosate (ROUNDUP)	0.00	0.00	0.00
2,4-D	2.38	0.20	2.85
atrazine	5.97	-	-
cyanazine(BLADEX)	6.09	-	-
chlorsulfuron(GLEAN)	6.44	-	-
metribuzin(LEXONE)	4.50	-	-
fluvalinate (MAVRIK)[y]	5.69	-	-
dienochlor (PENTAC)[y]	10.00	-	-
diniconazole (SPOTLESS)[z]	-	2.85	6.55
HWG 1608[z] (Mobay Chemical Co.)	-	0.05	6.40
propinconazole (TILT)[z]	-	2.35	5.75

w. 5 cm sections from above the nodes.
x. Dip = straws dipped into solution. Spray = straws sprayed solution with Devilbiss Atomizer no. 152.
y. Miticides commonly used in the greenhouse.
z. Experimental Foliar Fungicides.

TABLE 2-3

ASCOCARPS PER STRAW WITH DIP AND SPRAY
HERBICIDE APPLICATION IN EXPERIMENT 2

STRAW TYPE	MEAN[xy]
CULM	3.04 A[z]
CULM + SHEATH	2.77 A

x. 5 cm sections from above the nodes.
y. Average of dip and spray treatments.
z. Numbers followed by the same letter are not significantly (P= 0.05) different.

TABLE 2-4

ASCOCARPS PER STRAW ON CULM AND CULM + SHEATH
TISSUE IN EXPERIMENT 2

APPLICATION	MEAN[xy]
SPRAY	3.86 A[z]
DIP	1.95 B

x. 5 cm sections from above the nodes.
y. Average of culm and culm+sheath tissue.
z. Numbers followed by the same letter are significantly (P= 0.05) different.

TABLE 2-5

ASCOCARPS OF *Pyrenophora tritici-repentis* PER STRAW[y] WITH DIP APPLICATION OF HERBICIDES

HERBICIDE	RANKED MEAN
CONTROL + SURF.	25.75 A[z]
CONTROL	22.00 A
Bromoxynil(BUCTRIL)	13.75 B
2,4-D	13.50 B
PARAQUAT	12.50 B
Dicamba(BANVEL)	10.00 B
Glyphosate(ROUNDUP)	4.00 C

y. 5 cm sections from above the nodes.
z. Numbers, derived from the Kruskal-Wallis test for comparing non-parameteric data, followed by the same letter are not significantly different (P = 0.05).

CHAPTER 3: EFFECTS OF REDUCED TILLAGE SYSTEMS ON ASCOCARP PRODUCTION OF *P. tritici-repentis*

INTRODUCTION

Pyrenophora tritici-repentis (Died.) Drechs., causal agent of wheat (*Triticum avestivum*) tan spot, is an ascomycete which overwinters saprophytically on infested wheat residue. Ascocarps are formed on the residue and contain ascospores that are released in the spring, as primary inoculum, to infect the new wheat crop. These primary infections are followed by secondary cycles initiated after conidia production.

Previous studies by other investigators have shown a direct relationship between the amount of infested residue and the amount of disease and yield loss (5,22). In this thesis (Chapter 1) it has been shown that when the residue is kept at a constant level, the amount of disease and yield loss can be influenced by the ascocarps/m^2. Greenhouse studies have shown a reduction in ascocarp production of *P. tritici-repentis* on wheat straw treated with glyphosate herbicide (Roundup, Monsanto Agriculture Co., St. Louis, MO.) (Chapter 2 this thesis, 25).

Two experiments are described in this chapter. The purpose of the first experiment was to determine the amount of residue reduction and possible reduction of ascocarps/g in mowed vs. unmowed stubble in a stubble-mulched field. The

second experiment was based on the results of the first experiment and the results of the second chapter of this thesis. Different tillage practices combined with Roundup herbicide were used to test their effect on ascocarp production on infested wheat residue.

METHODS AND MATERIALS

The first experiment was conducted to compare ascocarp production by P. tritici-repentis on wheat residue in mowed vs. unmowed stubble in a stubble mulched wheat field in northcentral Kansas (Minneapolis, KS). Plots (7.8 x 18.8m) were set up in a completely randomized design with four replications. The amount of residue prior to any treatments was 570 g/m^2 (5085 lbs/acre). The mowed plots were mowed on July 16 with a rotary mower 10 cm high before any other tillage operations were preformed. This reduced the straws to about 10 cm lenghts. Both treatments then recieved the same tillage treatments, which where as follows:

July 16- chisel (10 cm twisted shovels, 40 cm centers) with coulters.

July 17- same implement as above diagonal to previous work pattern.

August 18- sweeps (45 cm wide, 30 cm centers) on chisel.

September 2- field cultivator (20 cm sweeps, 17.5 cm centers).

Residue from each plot was sampled September 21, the normal planting date, after all tillages had been completed. A 900 cm^2 frame was randomly tossed once into each plot and the residue above the soil surface collected. The samples were washed in water to remove soil and rinsed in 95% ethanol to kill any insects or mites. Leaf/sheath and culm tissue were separated and weighed, and ascocarps (>150 um on leaf and >300 um on culm) were counted (16). The g/m^2 of residue, ascocarps/g and ascocarps/m^2 for mowed vs. unmowed treatments were compared statistically.

In the second experiment various tillage and herbicide treatments were compared in the field to assess their effect on ascocarp production by P. tritici-repentis in its saprophytic stage on wheat residue. A plot (23m x 60m) at the Rocky Ford Experiment Farm near Manhattan, KS was planted with the winter wheat variety Arkan September 26, 1986. In November, primary inoculum of P. tritici-repentis was spread over the plot. This inoculum consisted of wheat straw from research plots infected with tan spot the previous growing season as well as oat kernels colonized by P. tritici-repentis (8.2g per m^2) (19).

The wheat was harvested July 6, 1987 and 1.3 x 7.5m plots were laid out using the untracked stubble left between the combine tires, with 2m of mowed stubble left as borders between the plots. Five tillage treatments were applied in

a randomized complete block design with 5 replications. Each plot contained 2 subtreatments, Roundup vs. Poast herbicide treatment, in a split-plot arrangement.

The five tillage treatments were:

1. No-till: stubble left undisturbed.
2. Flattened: stubble mowed at ground level with a sickle-type mower.
3. Mow and Chisel: The stubble was mowed with a rotary mower, the straw evenly distributed over the plot, then chiseled with straight chisel points on 30 cm centers, 20 cm deep.
4. Minimum Tillage: A heavy disc was used to knock down and partially bury the stubble, then the plot was chiseled one week later. A roto-tiller was used just prior to planting, the last week in September.
5. Stubble Mulch: Similar to minimum tillage, with the additions of sweep points used on a chisel 6 weeks after harvest, 2 passes with a roto-tiller 8 weeks after harvest (first week in September), and one roto-tiller treatment the last week in September, a week prior to planting the wheat.

These five treatments were selected to leave differing levels of residue on the soil surface at planting time, with the no-till treatment having the most residue and the stubble mulch treatment having the least. The treatments were also chosen to vary the time when the residue came in contact with

the soil, the stubble mulch treatment providing the longest period of contact between the residue and the soil.

The herbicide subplots of the treatments consisted of Roundup or Poast herbicides randomly assigned to each subplot. Roundup was used because it was the most effective herbicide for controlling ascocarp formation by P. tritici-repentis on infested wheat straw in the greenhouse in a previous experiment (25, Chapter 2 this thesis). Roundup also controlled weeds in the plots; for comparison, Poast was used to control grassy weeds on the check treatment. Poast did not limit ascocarp formation by P. tritici-repentis on wheat straw in the greenhouse experiment.

Roundup was applied to the subplots not treated with Poast, with a pump-type hand sprayer, immediately after harvest and before any tillages were performed. The rate used was 32 ounces (946 ml) of formulated product in 50 gallons (189 l) of water per acre, to insure thorough coverage of the residue. Poast was applied at the same time at 40 ounces (1184 ml) of formulated product in 20 gallons (76 l) of water per acre.

At one and two months after harvest, the no-till, flattened and minimum-till plots received an additional application of herbicides to control weeds. Roundup was applied at 12 ounces (355 ml) of formulated product in 20 gallons (76 l) of water per acre to the Roundup subplots. Poast was applied to the Poast subplots. In the second month,

the mow and chisel plots were also treated with herbicides to control weeds. Poast was applied thereafter as needed to control grassy weeds in the Poast split-plots. Just prior to planting, 2,4-D was applied at 0.5 lb. active ingredient (438 g) in 20 gallons (76 l) of water per acre to the whole plots of no-till, flattened, and minimum-till plots to control the small broadleaf weeds.

The plots were planted September 30 with a 5-row hoe drill having 23 cm row spacing, after shallow-fluted coulters had been used to slice the residue where the drill openers would go. The no-till plot was planted by hand, with the seed sprinkled in the coulter slots, because the hoe drill did not have enough clearance to allow the residue to pass through.

Photographs, taken October 6 from 2 m above the plot, were used to measure the residue on the soil surface after planting, using the grid point system (12).

Residue from the plots was sampled January 1988. Four subsamples were taken from each subplot using 12.5 cm diameter plastic hoops randomly tossed to mark the areas to be sampled. Any residue within the cylinder above the ground marked by the hoops was cut out with scissors and transferred to paper bags. Each sample (the 4 combined subsamples) was rinsed with water on a #20 screen to wash off the soil, then rinsed with 95% ethanol to kill insects and mites and allowed to air dry. Wheat seedlings, weeds, and wheat heads were discarded before the samples were weighed. The residue was cut into 5-cm

pieces, thoroughly mixed, and random subsamples (each 2 grams) were taken from each sample. The straw pieces in each subsample were sorted into 3 classes: sheath tissue, culm tissue bearing ascocarps, and culm without ascocarps. The sheath component was weighed separately and discarded because most of the sheath tissue was observed to have deteriorated through the winter. The ascocarps >300 um were counted on a subsample (0.5-0.8g) of culm. The total sample weight, percent and total weight of ascocarp-bearing culm, ascocarps/g of culm and ascocarps per sample were recorded and statistically analyzed for differences among tillage and/or herbicide treatments (23).

A disease rating was taken on the wheat plants, April 13, 1988, using the 0-5 scale described in Chapter 1 of this thesis. Three leaves from each of 5 plants were randomly selected from each subplot and rated for severity. The number of lesions per leaf was also recorded but not used in the analyses.

RESULTS

The results from the first experiment are shown in Table 3-1. The grams of straw/m^2, ascocarps/g and ascocarps/m^2 for the culm tissue were significantly (unless otherwise noted P= 0.05) lower in the mowed treatment than in the unmowed treatment. The weight of leaf tissue (g/m^2) was not significantly different between treatments whereas the

ascocarps/g and ascocarps/m^2 were significantly lower in the mowed treatment than in the unmowed treatment.

For experiment two the percentages of soil surface covered with wheat residue are shown in Table 3-2. The percent cover ranged from 12 in the stubble-mulch plots to 91 in the no-till plots.

The residue weights (Table 3-2) ranged from 35 g/m^2 in the stubble-mulch plots to 376 g/m^2 in the no-till plots. The stubble-mulch and minimum-till plots were not significantly different from each other. The minimum-till and mow/chisel plots were not significantly different from each other in residue weight, but were significantly lower than the flattened and no-till plots. The flattened plots had significantly less residue than the no-till plots.

The ascocarps/g of residue ranged from 949 in the stubble mulch plots to 1295 in the no-till plots, but there were no statistical differences between the tillages until P= 0.22.

The no-till plots had significantly more ascocarps/sample than all the other plots. The flattened and mow/chisel plots were not significantly different from each other, but the flattened treatment had significantly more ascocarps than the minimum-till and stubble-mulch plots. The mow/chisel, minimum-till and stubble-mulch plots were not significantly different from each other.

The disease ratings (Table 3-3) for leaf 1 in different tillage treatments were significantly different at P= 0.093, with a range for the average ratings per leaf from 0.42 in the stubble-mulch to 0.70 in the flattened plots. At P= 0.05 these 2 tillages were significantly different from each other but not from the other tillages.

The disease ratings for leaf 2 ranged from 0.93 for stubble-mulch plots to 1.5 for no-till plots. The stubble-mulch ratings were significantly lower than all the other plots except minimum-till.

The disease ratings for leaf 3 ranged from 1.78 in the stubble-mulch plots to 2.36 in the no-till plots. The stubble-mulch plots had significantly lower ratings than all other plots. The no-till plots were not significantly different from the flattened plots but were different from all other plots.

The combined results of leaves 1 and 2 showed the stubble-mulch plots having significantly lower ratings than all other plots except the minimum-till plots. All the other plots were not significantly different from each other.

The combined results of all the leaves showed the stubble-mulch plots significantly different from all other plots. The mow/chisel and minimum-till plots were not significantly different from each other.

There was no significant difference between the Roundup and Poast sub-plots in any of the categories (Table 3-4).

No differences were shown between the Roundup and Poast split-plots in any of the leaf ratings(Table 3-5)

DISCUSSION

The results from the first tillage experiment showed that, compared with unmowed stubble, mowing the stubble prior to tilling reduces the amount of residue remaining on the soil surface after stubble-mulching. If mowing reduces the number of ascocarps/g such that the level of ascocarps/m^2 would be below the levels mentioned in Chapter 1 (< 2,500 in 1987 and < 5,000 in 1988) it would be very beneficial as a method of reducing the primary inoculum of Pyrenophora tritici-repentis in a wheat field. The ascocarps/m^2 have been shown to be directly related to the amount of disease (Chapter 1 of thesis) and this experiment shows that mowing and possibly other types of tillage operations could help control tan spot while leaving residue on the soil surface for erosion control.

For experiment two a range in the percent of wheat straw residue covering the soil, just prior to wheat planting, was achieved as desired, but most of the differences in the percent of wheat straw covering the soil were determined by the last few tillages prior to planting. This would not be the typical practice in a reduced tillage situation in a year with normal rainfall. Usually the straw is worked into the soil over a period of time before planting. In 1988, there was a fairly long dry period after harvest when there was no rain

to settle the straw and no tillages were needed to control vegetation. Much of the residue in the minimum till and stubble mulch plots was not tilled into the soil until late in the season (8 weeks after harvest). The ascocarp numbers might have been reduced even more if the residue had been in longer contact with the soil, improving the conditions that benefit other straw-borne saprophytes that would compete with P. tritici-repentis (2,15). This could be why there were no significant differences in number of ascocarps per gram of straw among the different tillages. The mow/chisel plots also may have been affected by the lack of rain to settle the straw because there was no significant difference between the short lengths of straw in the mowed plots and the longer straws in the no-till and flattened plots. The lack of differences between these two tillages (cf. 1986 unmowed vs. mowed stubble experiment results) might be attributed partially to the lack of rain after harvest where the conditions were not favorable for the straw-borne saprophytes to compete with P. tritici-repentis in straw above the soil surface, even if the short pieces of straw offered more opportunities for colonization by the saprophytes.

The 1987 harvest was delayed by rain for 3 weeks after the crop was mature. This could have allowed P. tritici-repentis to become established before any of the treatment measures could be applied, lowering the effectiveness of any treatments in reducing ascocarp numbers, since ascocarp

initials were seen within two weeks after harvest (data not shown).

The lack of differences between the Roundup and Poast treated split-plots could be due to differences between the microclimates of the split-plots. The Roundup plots were weed-free most of the season whereas the Poast plots had more broadleaves as well as grasses that were not as effectively controlled. The weeds could have raised the relative humidity around the straw by shading, and blocking air movement. The higher relative humidity could have been more conducive to the growth of saprophytic fungi potentially antagonistic to P. tritici-repentis (2,15). Also, the delay of harvest could have limited the effectiveness of Roundup in limiting ascocarp development (22) because the fungus had more time to become established in the tissue. There is also a possibility that in field conditions Roundup has a deleterious effect on antagonists of P. tritici-repentis. However, these results could simply mean that Roundup is not an effective method of controlling ascocarp formation by P. tritici-repentis on wheat straw. The concentrations of Roundup necessary for reducing P. tritici-repentis ascocarp production may not be feasible in a field situation.

The leaf ratings showed that lowering the primary inoculum could also reduce the tan spot epidemic; however, the differences between the different tillages might have been more pronounced if the wheat stands had been uniform. The

stubble mulch plots had the tallest, thickest stand of wheat due to better seed-bed conditions at planting. The taller crop canopy and thicker stand could have had an effect on raising the relative humidity in the plot, increasing the successful tan spot infections significantly during the dry spring 1988 conditions that were very limiting to a tan spot epidemic. The Roundup sub-plots also had better wheat stands than the Poast sub-plots because of the better moisture and seedbed conditions which could have contributed some to the lack of difference between the level of disease in the herbicide treatments.

In summary, our experimental results show some promise for developing a method of controlling tan spot epidemics by reducing the primary inoculum. As an example, mowing reduced ascocarp numbers 68-78% during both years. However, it appears that timeliness is a critical factor and that a combination of methods may offer the best probability for success in the future. Treatments should be performed as soon as possible. These experiments point to areas that may need to be improved upon in future experiments such as timing of treatments and consistant planting/plant populations to get an accurate look at various control methods.

TABLE 3-1

Pyrenophora tritici-repentis ASCOCARP NUMBERS ON MOWED AND UNMOWED RESIDUE FROM A STUBBLE MULCH FIELD

Treatment[y]	straw g/m^2		ascocarps/g		ascocarps/m^2	
	culm	leaf	culm	leaf	culm	leaf
unmowed	64 A[z]	13 A	192 A	1,187 A	12,253 A	15,583 A
mowed	24 B	8 A	73 B	544 B	1,770 B	4,154 B

y. After harvest, straw was mowed or unmowed before applying a series of stubble-mulch tillages to all plots. Data were collected September 21, 1986.

z. Numbers in each catagory with different letters are significantly (P=.05) different from each other.

TABLE 3-2

QUANTITY AND INFESTATION LEVEL OF STRAW IN TILLAGE PLOTS, JANUARY 1988

TILLAGE	PERCENT COVER	RESIDUE (g/m^2)	ASCOCARPS PER GM	ASCOCARPS PER M^2
NOTILL	91 A[z]	387 A	490 A	189,084 A
FLATTEN	78 B	272 B	412 A	112,347 B
MOW/CHISEL	51 C	155 C	409 A	61,355 BC
MINIMUM TILL	28 D	92 CD	412 A	38,605 C
STUBBLE	12 E	36 D	380 A	13,649 C

z. Means followed by the same letter within a column are not significantly different(P= 0.05).

TABLE 3-3

LEAF DISEASE RATINGS[y] IN TILLAGE PLOTS

TILLAGE	LEAF 1	LEAF 2	LEAF 3	LEAVES 1 AND 2	LEAVES 1, 2, &3
NOTILL	.58 AB[z]	1.50 A	2.36 A	1.07 A	1.48 A
FLATTEN	.70 A	1.44 AB	2.28 AB	1.04 A	1.47 A
MOW/CHISEL	.55 AB	1.31 AB	2.14 B	.93 A	1.33 AB
MINIMUM	.52 AB	1.18 BC	2.10 B	.85 AB	1.28 B
STUBBLE	.42 B	.93 C	1.78 C	.68 B	1.04 C

y. Average rating per leaf (0-5 scale). Plants rated on 4/13/88, wheat at Feekes' Scale 6.
z. Means followed by the same letter within a column are not significantly different (P= 0.05).

TABLE 3-4

QUANTITY AND INFESTATION LEVEL OF STRAW IN PLOTS[x] TREATED WITH ROUNDUP AND POAST

HERBICIDE	SAMPLE WT.[y]	ASCOCARPS PER GRAM	ASCOCARPS PER M^2
ROUNDUP	198.1 A[z]	1076.9 A	89,764 A
POAST	171.5 A	1119.9 A	73,363 A

x. Plots sampled January 1988.
y. Grams per m^2.
z. Means followed by the same letter within a column are not significantly different(P= 0.05).

TABLE 3-5

LEAF DISEASE RATINGS[y] IN PLOTS TREATED WITH ROUNDUP AND POAST

HERBICIDE	LEAF 1	LEAF 2	LEAF 3	1 AND 2	1,2&3
ROUNDUP	1.1 A[z]	2.5 A	4.3 A	1.8 A	2.6 A
POAST	1.1 A	2.6 A	4.2 A	1.9 A	2.6 A

y. Average rating per leaf (0-5 scale). Plants rated on 4/13/88, wheat at Feekes' Scale 6.
z. Means followed by same letter within a column are not significantly different (P=.05).

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PRIMARY INOCULUM OF *Pyrenophora tritici-repentis* ON WHEAT AS AFFECTED BY CULTURAL CONTROLS IN REDUCED TILLAGE, AND ITS EFFECT ON EPIDEMIC DEVELOPMENT

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ABSTRACT

Field experiments were conducted to determine how numbers of ascocarps of Pyrenophora tritici-repentis (causal agent of tan spot) affected the amount of disease and yield on wheat. Different levels of ascocarps/m^2 were placed in wheat plots two different seasons, and measurements of disease were taken weekly through the tan spot epidemic. Yield measurements taken at harvest. There were statistical differences among the Areas Under the Disease Progress Curve (AUDPC) for the different primary inoculum levels, with a positive regression between the AUDPC and primary inoculum level. Statistical differences were shown between the yields, however the regression of yield on primary inoculum level was not significant though there was a negative trend.

Different herbicides commonly used in reduced-tillage wheat farming were applied to pieces of wheat straw naturally infected with P. tritici-repentis and incubated in the greenhouse. The numbers of ascocarps on the straws were counted after one month. Straws treated with the glyphosate-containing herbicide Roundup produced no ascocarps, which was significantly lower than values for the other herbicides tested.

Mowed vs. unmowed stubble in a stubble-mulch field infested with P. tritici-repentis were compared. Measurements were taken in the fall on residue/m^2, ascocarps/g and ascocarps/m^2. There were statistical differences for all of

these dependent variables, with the mowed treatments having lower numbers. In a separate experiment different tillage practices were applied in a wheat stubble field infested with P. tritici-repentis, and wheat was planted in the plots in the fall. Measurements were taken in the fall on the amount of residue/m^2, ascocarps/g of residue and ascocarps/m^2, and in the spring on the amount of disease. There were statistical differences in the residue/m_2, ascocarps/m^2 and the amount of disease, but not in the amount of ascocarps/g.